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U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

ATTORNEY'S DOCKET NUMBER

TRANSMITTAL LETTER TO THE UNITED STATES

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DESIGNATED/ELECTED OFFICE (DO/EO/US)

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 1.5)

CONCERNING A FILING UNDER 35 U.S.C. 371

09/509428

INTERNATIONAL APPLICATION NO.

INTERNATIONAL FILING DATE

PRIORITY DATE CLAIMED

PCT/SE98/01738

29 September 1998

30 September 1997

TITLE OF INVENTION

AN ELECTRIC POWER PLANT

APPLICANT(S) FOR DO/EO/US

Mats LEIJON et al

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☐ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
 - a. ☒ is transmitted herewith (required only if not transmitted by the International Bureau).
 - b. ☐ has been transmitted by the International Bureau.
 - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☐ A copy of the International Search Report (PCT/ISA/210).
8. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
 - a. ☒ are transmitted herewith (required only if not transmitted by the International Bureau).
 - b. ☐ have been transmitted by the International Bureau.
 - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
 - d. ☐ have not been made and will not be made.
9. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
10. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
11. ☐ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

Items 13 to 18 below concern document(s) or information included:

13. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
A **SECOND** or **SUBSEQUENT** preliminary amendment.
16. ☐ A substitute specification.
17. ☐ A change of power of attorney and/or address letter.
18. ☐ Certificate of Mailing by Express Mail
19. ☐ Other items or information:

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 1.5) 09/509428	INTERNATIONAL APPLICATION NO. PCT/SE98/01738	ATTORNEY'S DOCKET NUMBER 705/72341-2
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20. The following fees are submitted:.

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :

- | | |
|---|-----------------|
| <input type="checkbox"/> Search Report has been prepared by the EPO or JPO | \$840.00 |
| <input type="checkbox"/> International preliminary examination fee paid to USPTO (37 CFR 1.482)
. | \$670.00 |
| <input type="checkbox"/> No international preliminary examination fee paid to USPTO (37 CFR 1.482)
but international search fee paid to USPTO (37 CFR 1.445(a)(2)) | \$760.00 |
| <input checked="" type="checkbox"/> Neither international preliminary examination fee (37 CFR 1.482) nor
international search fee (37 CFR 1.445(a)(2)) paid to USPTO | \$970.00 |
| <input type="checkbox"/> International preliminary examination fee paid to USPTO (37 CFR 1.482)
and all claims satisfied provisions of PCT Article 33(2)-(4) | \$96.00 |

ENTER APPROPRIATE BASIC FEE AMOUNT =

Surcharge of **\$130.00** for furnishing the oath or declaration later than ☐ 20 ☒ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	
Total claims	32 - 20 =	12	x \$18.00	\$216.00
Independent claims	2 - 3 =	0	x \$78.00	\$0.00
Multiple Dependent Claims (check if applicable).			<input type="checkbox"/>	\$0.00

Multiple Dependent Claims (check if applicable).

TOTAL OF ABOVE CALCULATIONS

Reduction of 1/2 for filing by small entity, if applicable. Verified Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28) **(check if applicable)**.

SUBTOTAL

Processing fee of **\$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)).

TOTAL NATIONAL FEE

Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable)**.

TOTAL FEES ENCLOSED

**Amount to be:
refunded**

charged

- ☒ A check in the amount of **\$1,316.00** to cover the above fees is enclosed.
- ☐ Please charge my Deposit Account No. _____ in the amount of _____ to cover the above fees.
A duplicate copy of this sheet is enclosed.
- ☒ The Commissioner is hereby authorized to charge any fees which may be required, or credit any overpayment to Deposit Account No. **23-0575** A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

SIGNATURE

John P. DeLuca

NAME _____

25,505

REGISTRATION NUMBER

March 28, 2000

DATE _____

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END OF DISPLAY

430 Rec'd PCT/PTO 28 MAR 2000

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:)	PATENT
)	
Mats LEIJON et al.)	Group: To Be Assigned
)	
Serial No: New Application)	Examiner: To Be Assigned
Based on PCT/SE98/01738)	
)	
Filed: March 28, 2000)	
)	
AN ELECTRIC POWER)	
PLANT)	

PRELIMINARY AMENDMENT

March 28, 2000

Commissioner of Patents
and Trademarks
Washington, D.C. 20231

Sir:

Prior to initial examination merits, please amend the above-identified application as follows:

IN THE CLAIMS:

Please amend the claims as follows:

Claim 1. (Twice Amended) An electric power plant, comprising at least one rotating electric machine [intended to be connected] for connection directly to a distribution or transmission network [and] comprising at least one electric winding, [characterized in that the winding comprises] including at least one electric conductor, a first layer with semiconducting properties surrounding the conductor, an insulating layer surrounding the first layer, and a second layer with semiconducting properties surrounding the insulating

layer, and [in that] a brushless excitation system [is adapted to excite] for exciting the electric machine.

Claim 2. (Twice Amended) [A] The power plant according to claim 1, [characterized in that] wherein the conductor has a potential [of] and the first layer [is essentially] has a potential equal to the potential of the conductor.

Claim 3. (Twice Amended) [A] The power plant according to claim 1 [or 2, characterized in that] , wherein the second layer [is adapted to form] forms [essentially] an equipotential surface surrounding the conductor.

Claim 4. (Twice Amended) [A] The power plant according to claim 3, [characterized in that] wherein the second layer is connected to a predetermined potential.

Claim 5. (Twice Amended) [A] The power plant according to claim 4, [characterized in that] wherein said predetermined potential is ground potential.

Claim 6. (Twice Amended) [A] The power plant according to [any of the preceding claims; characterized in that] claim 1, wherein at least two adjacent layers of the winding of the machine have [essentially] substantially equal coefficients of thermal expansion.

Claim 7. (Twice Amended) [A] The power plant according to [any of the preceding claims, characterized in that] claim 1, wherein the conductor comprises a number of [strands] conductive elements, at least some of which being in electrical contact with one another.

Claim 8. (Twice Amended) [A] The power plant according to [any of the preceding claims, characterized in that] claim 1, wherein each one of said

[three] layers is fixed to adjacent layers along essentially [the] a whole contact surface therebetween.

Claim 9. (Twice Amended) [A] The power plant according to [any of the preceding claims, characterized in that] claim 1, wherein said layers [are adapted to] adhere to one another even when the insulated conductor is bent.

Claim 10. (Twice Amended) An electric power plant, comprising at least one rotating electric machine of alternating-current type, [intended to be connected] for connection directly to a distribution or transmission network and comprising at least one magnetic core and at least one electric winding, [characterized in that] wherein the winding is formed from a cable comprising one or more current-carrying conductors, each conductor having a number of [strands] conductive elements, an inner semiconducting layer arranged around each conductor, an insulating layer of solid insulating material arranged around said inner semiconducting layer, and an outer semiconducting layer arranged around the insulating layer, and [in that] a brushless excitation system [is adapted to excite] for exciting the electric machine.

Claim 11. (Twice Amended) [A] The power plant according to claim 10, [characterized in that] wherein said cable comprises a sheath.

Claim 12. (Twice Amended) [A] The power plant according to [any of the preceding claims, characterized in that] claim 1, wherein the machine has a field winding for connection to a supply voltage and wherein the brushless excitation system comprises a rotating part with an exciter, [connected to] controllable semiconductor elements connected thereto; and [with] associated control equipment for rectifying the supply voltage obtained for supplying the field winding of the machine.

Claim 13. (Twice Amended) [A] The power plant according to claim 12, [characterized in that] including stationary regulator equipment and wherein a communication unit is adapted for wireless communication between the stationary regulator equipment and the control equipment included in the rotating part.

Claim 14. (Twice Amended) [A] The power plant according to claim 12 [or 13, characterized in that] , wherein the exciter [is of] comprises a synchronous machine [type with] including a rotating stator winding.

Claim 15. (Twice Amended) [A] The power plant according to claim 12, wherein the machine has a magnetic core for carrying flux, and wherein [or 13, characterized in that] the exciter comprises a permanent-magnet generator[, in which] including stationary permanent magnets [are] supplemented by turns of the winding turns for [controlled] controlling changes [of] in the flux.

Claim 16. (Twice Amended) [A] The power plant according to claim 12 [or 13, characterized in that] , wherein the exciter comprises an asynchronous machine [with] including three rotating windings and reversed direction of rotation.

Claim 17. (Twice Amended) [A] The power plant according to [any of claims 12 – 16] claim 12, comprising a machine for auxiliary power generation, [characterized in that] wherein the exciter [is designed with] includes double stator windings for supplying at least one of the electric machine, [or] the main machine [as well as] , and the auxiliary power machine.

Claim 18. (Twice Amended) [A] The power plant according to claim 17, [characterized in that] wherein the double stator windings are each connected to [each of their] respective associated controllable semiconductor elements with respective control equipment for individual control of the supply of the auxiliary power machine and the electric machine.

Claim 19. (Twice Amended) [A] The power plant according to claim 17 [or 18, characterized in that] , wherein the control equipments [are adapted to] generate control pulses to the controllable semiconductor elements for [in a manner] self-compensating for variations in the supply voltage to the semiconductor elements.

Claim 20. (Twice Amended) [A] The power plant according to [any of claims 12-19, characterized in that] claim 12, wherein the controllable semiconductor elements [are adapted to] form a thyristor bridge.

Claim 21. (Twice Amended) [A] The power plant according to [any of claims 12-20, characterized in that] claim 12, wherein a filter transformer is [adapted] operative to determine [the] a phase position for firing the controllable semiconductor elements[for adaptation of the voltage].

Claim 22. (Twice Amended) [A] The power plant according to [any of claims 13-21, characterized in that] claim 13, wherein the communication unit comprises stationary transmitters and/or receivers connected to the regulator equipment as well as receivers and/or transmitters on the rotating part connected to the control equipment for communication therebetween with frequency-modulated infrared light.

Claim 23. (Twice Amended) [A] The power plant according to [any of claims 17-22, characterized in that] claim 17, wherein the auxiliary power

machine is adapted, via the converter, to supply the stationary field winding of the rotating exciter.

Claim 24. (Twice Amended) [A] The power plant according to [any of claims 17-23, characterized in that the] claim 17, including a regulator and an auxiliary power machine for producing an [the] output voltage, which output voltage of the auxiliary power machine is fed back, via [a] the regulator, to the controllable semiconductor elements for the auxiliary power machine for regulating the voltage by excitation control.

Claim 25. (Twice Amended) [A] The power plant according to [any of claims 13-24, characterized in that] claim 13, wherein [the stationary part and the rotating part of the communication unit are adapted for] wireless communication includes at least one of, [capacitively or inductively or by] capacitive, inductive, radio communication [or] , and optical connection.

Claim 26. (Twice Amended) [A] The power plant according to [any of the preceding claims, characterized in that] claim 12, including a unit [is adapted] operative to detect ground faults in the supply of the field winding of the electric machine.

Claim 27. (Twice Amended) [A] The power plant according to [any of the preceding claims, characterized in that] claim 1, including transducers [are adapted] operative to measure the temperature in the field winding of the electric machine.

Claim 28. (Twice Amended) [A] The power plant according to [any of claims 12-27, characterized in that] claim 12, including an overvoltage protection device, controlled by the control equipment [is] connected across the field winding of the electric machine.

Claim 29. (Twice Amended) [A] The power plant according to claim 28, [characterized in that] including current measuring means are arranged on [the] AC and DC sides of the controllable semiconductor elements to measure currents, and [that] the overvoltage protection device is [adapted] operative to be reset in response to the difference between [these] the currents fulfilling a predetermined condition.

Claim 30. (Twice Amended) [A] The power plant according to [any of claims 13-29, characterized in that] claim 13, wherein the electric machine produces an output voltage [of the electric machine] which is fed back to the regulator equipment for adaptation of the supply voltage to [the] actual operating conditions.

Claim 31. (Twice Amended) [A] The power plant according to [any of claims 17-30, characterized in that] claim 17, wherein the auxiliary power machine comprises at least one electric winding with at least one electric conductor, a first layer with semiconducting properties surrounding the conductor, an insulating layer surrounding the first layer, and a second layer surrounding the insulating layer.

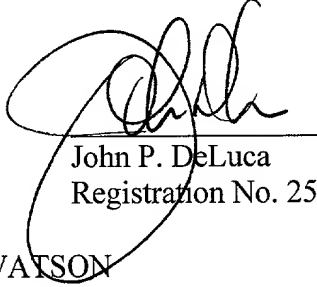
Claim 32. (Twice Amended) Use of a rotating electric machine in an electric power plant according to [any of the preceding claims] claim 1[, said machine being intended to be connected directly to a distribution or transmission network and comprising at least one electric winding, said winding comprising at least one electric conductor, a first layer with semiconducting properties surrounding the conductor, an insulating layer surrounding the first layer, and a second layer with semiconducting properties surrounding the insulating layer, and a brushless excitation system for exciting the electric machine].

REMARKS

Applicants have amended the claims in order to delete the multiple dependencies therefrom and to place them in better U.S. format. In the event that any multiple dependencies remain in the claims, it is respectfully requested that said multiple dependencies be deleted and reference be made to the immediately preceding claim.

Examination on the merits is earnestly solicited.

Respectfully submitted,



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AN ELECTRIC POWER PLANT

Technical Field

The present invention relates to an electric power plant comprising at least
5 one rotating main electric machine, intended to be connected directly to a distribu-
tion and transmission network and comprising at least one electric winding. The
invention relates also to the use of a rotating electric machine in an electric power
plant.

10 Background

The rotating electric machine, which is included in the power plant, may
for example be a synchronous machine, a double-fed machine, an external pole
machine or a synchronous flux machine.

A transformer has been used up to the present to step-up the voltage to
15 the level of the network i.e., in the range of 130 - 400 kV in order to connect ma-
chines of the type mentioned above to distribution or transmission networks,
commonly referred to below as power networks.

A generator with a rated voltage of up to 36 kV is described by Paul
Siedler in an article entitled "36 kV Generators Arise from Insulation Research", in
20 Electrical World, 15 October 1932, pp. 524-527. These generators comprise
windings of high voltage cable, in which the insulation is divided into different lay-
ers having different dielectric constants. The insulation material being utilized
consists of different combinations of the following three components: mica foil-
mica, lacquer and paper.

25 It has proved that, by manufacturing the above-mentioned winding for the
machine of an insulated electric high voltage conductor having a solid insulation of
a similar type as for cables for the transmission of power, the voltage of the ma-
chine may be increased to such levels that the machine may be connected directly
to any power network without an intermediate transformer. The transformer may
30 thus be dispensed with. A typical power range for these machines is 30 - 800 kV.

The aim of the present invention is to provide an electric power plant hav-
ing at least one main electric machine which is directly connected to transmission

and distribution networks and which is magnetizable from an excitation system which lacks slip rings and is simple to maintain.

Summary of the invention

5 This aim is achieved by an electric power plant of the kind described in the introductory part of the description, with the characteristic features described in Claim 1.

The insulated conductor or high voltage cable used in the present invention is flexible and bendable and of the type described in more detail in WO 10 97/45919 and WO 97/45847. Additional descriptions of the insulated conductor or cable can be found in WO 97/45918, WO 97/45930 and WO 97/45931.

Thus, in a device according to the invention the windings are preferably composed of cables having solid, extruded insulation, of a type currently used for power distribution, such as XLPE cables or cables having EPR insulation. Such a cable comprises an inner conductor composed of one or more strands, an inner 15 semiconducting layer surrounding the conductor, a solid insulating layer surrounding the inner semiconducting layer and an outer semiconducting layer surrounding the insulating layer. Such cables are bendable, which is an important property in this respect since the technology for the machines of the invention, is based primarily on a winding system in which the winding is formed from cables which are 20 bent during assembly. The bending ability of an XLPE cable normally corresponds to a radius of curvature of approximately 20 cm for a cable with a diameter of 30 mm, and a radius of curvature of approximately 65 cm for a cable with a diameter of 80 mm. In the present application the designation bendable is used to indicate 25 that the winding is bendable down to a radius of curvature in the order of four times the cable diameter, preferably eight to twelve times the cable diameter.

The winding should be constructed so as to retain its properties even when it is bent and when it is subjected to thermal or mechanical stress during operation. It is vital that the layers retain their adhesion to each other in this 30 respect. The material properties of the layers are decisive here, particularly their elasticity and relative coefficients of thermal expansion. In an XLPE cable, for example, the insulating layer consists of cross-linked, low-density polyethylene, and

the semiconducting layers consist of polyethylene with both soot and metal particles mixed therein. Changes in the volume as a result of temperature fluctuations are completely absorbed as changes in the radius of the cable and, thanks to the comparatively slight difference between the coefficients of thermal expansion of the layers in relation to the elasticity of these materials, the radial expansion of the cable may take place without the loss of adhesion between the layers.

The material combinations stated above should be considered by way of example only. Other combinations fulfilling the specified conditions as well as the condition of being semiconducting, i.e. having a resistivity within the range of 10^{-1} - 10^6 ohm-cm. e.g. 1 - 500 ohm-cm or 10 - 200 ohm-cm naturally also fall within the scope of the invention.

The insulating layer may consist, for example, of a solid thermoplastic material such as low-density polyethylene (LDPE), high-density polyethylene (HDPE), polypropylene (PP), polybutylene (PB), polymethyl pentene (PMP), cross-linked materials such as cross-linked polyethylene (XLPE), or rubber such as ethylene propylene rubber (EPR) or silicone rubber.

The inner and outer semiconducting layers may be of the same basic material but with particles of conducting material such as soot or metal powder mixed therein.

The mechanical properties of these materials, particularly their coefficients of thermal expansion, are affected relatively little by whether soot or metal powder is mixed therein or not, i.e. in the proportions required to achieve the conductivity necessary according to the invention. Thus, the insulating layer and the semiconducting layers have substantially the same coefficients of thermal expansion.

Ethylene-vinyl-acetate copolymers/nitrile rubber, butyl graft polyethylene, ethylene-acrylate copolymers and ethylene-ethyl-acrylate copolymers may also constitute suitable polymers for the semiconducting layers.

Even when different types of material are used as a base in the various layers, it is desirable for their coefficient of thermal expansion to be substantially the same. This is the case in the combination of the materials listed above.

The materials listed above have a relatively good elasticity, with an E-modulus of $E < 500$ MPa, preferably < 200 MPa. The elasticity is sufficient for any

minor differences between the coefficients of thermal expansion for the materials in the layers to be absorbed in the radial direction by the elasticity so that no cracks or other damage arise and so that the layers are not released from each other. The material in the layers is elastic, and the adhesion between the layers is at least of the same magnitude as the weakest of the materials.

The conductivity of the two semiconducting layers is sufficient to substantially equalise the potential along the respective layers. The conductivity of the outer semiconducting layer is sufficiently large to contain the electric field in the cable, but at the same time sufficiently small to not give rise to significant losses due to currents induced in the longitudinal direction of the layer.

Thus, each of the two semiconducting layers essentially constitutes one equipotential surface, and these layers will substantially enclose the electric field between them.

This does not, of course, exclude one or several semiconducting layers from being arranged additionally in the insulating layer.

According to advantageous embodiments of the power plant according to the invention, the brushless excitation system comprises a rotating part with an exciter connected to rotating controllable semiconductor elements with associated control equipment for rectifying the supply voltage obtained for supplying the field winding of the machine, and furthermore a communication unit is adapted for wireless communication between stationary regulator equipment and the control equipment which is included in the rotating part. By exploiting the controllable semiconductor elements in this way, improved regulating properties are achieved in that positive as well as negative excitation voltages can be achieved simultaneously with the simple maintenance characterizing brushless excitation systems. Faster response and transient times are obtained during network interference in that the excitation system can generate positive as well as negative excitation voltage.

According to other advantageous embodiments of the power plant according to the invention, the exciter is designed with double stator windings for the excitation of the main electric machine as well as the auxiliary power machine. The stator windings are hereby advantageously connected to each of their re-

spective controllable semiconductor elements with respective control equipment for individual control of the supply of the auxiliary power machine and the main electric machine. The control equipments are advantageously adapted to generate control pulses to the controllable semiconductor elements in a manner self-compensating for variations in the supply voltage to the semiconductor elements. Flux changes necessary for voltage variations suited to the excitation requirements of the machine will thereby not influence the excitation of a voltage regulated machine generating auxiliary power. A constant voltage at the auxiliary power busbar and a voltage rise for the generation of extra, temporary short-circuit power during faults are enabled by voltage regulation of the machine generating auxiliary power.

Brief description of the drawings

To explain the invention in greater detail, embodiments of the electric power plant according to the invention will now be described in more detail with reference to the accompanying drawings, wherein

Figures 1 to 3 show diagrams of three different embodiments of the power plant according to the invention,

Figure 4 shows a more detailed embodiment of the rotating part in the excitation system in connection with the embodiments according to Figures 1-3,

Figure 5 illustrates a principle for reduction of exciter losses by supply voltage, which is adapted to the requirements, to the controllable, rectified semiconductor elements in the form of a rotating thyristor bridge,

Figure 6 illustrates a principle for self-compensating control pulse generation for control of the rectifying semiconductor elements, and

Figure 7 shows a cross-section view of the insulated conductor which is used in machines in the power plant according to the invention.

Description of the preferred embodiments

Figure 1 shows a first embodiment of the electric power plant according to the invention, comprising an electric machine G1 and an auxiliary power machine in the form of a permanent-magnet generator G2. The machine G1 is excited by means of an excitation system comprising a rotating part 1 with an exciter G3, 5 controllable rectifying semiconductor elements in the form of a thyristor bridge 21 with a control-pulse generator 22, a bidirectional overvoltage protection device 24, and a rotating field winding 30 of the electric machine G1. Further, the rotating part 1 comprises control equipment 23 for control of the thyristor bridge 21 via the control pulse generator 22. The control equipment 23 is also connected to current-measuring members 25, 27 arranged on each side of the thyristor bridge 21. A filter transformer 28 is connected between the output side of the exciter G3 and the control pulse generator 22 and the control equipment 23 for determining and rotating the phase position for firing the thyristors for the purpose of voltage adaptation. Variations of the input voltage may thus be compensated for by control of the thyristor firing. 15

The rotating part 1 of the excitation system further comprises a supply device 26 for the electronic devices of the rotating part 1.

A bidirectional overvoltage protection device 24 serves as overvoltage protection for the field winding 30 and diverts induced currents in case of a fault. 20 The overvoltage protection device 24 comprises a current-limiting resistor 34, which makes possible continued operation when the overvoltage protection device 24 is activated. An activated protection device 24 is reset by temporary sign reversal of the field voltage.

25 The control equipment 23 is further connected to a rotating communication unit 29 for wireless communication with a stationary communication unit 34, which in turn is connected, via the control equipment 23, to regulator equipment 33 for control of the power stage, formed by the thyristor bridge 21 and the control pulse generator 22, from the regulator equipment 33. In this way, the excitation of the machine G1 is thus controlled from the stationary regulator equipment 33 by 30 regulating the degree of modulation of the thyristors of the bridge 21.

Other monitoring and regulating functions may also be carried out from the stationary regulator equipment 33.

The signal transmission between the stationary and rotating communication units 34, 29 may be performed with the aid of frequency-modulated infrared light. Each unit 34, 29 is then provided with at least one transmitting and one receiving part, comprising a number of light-emitting diodes. The number of light-emitting diodes and the location on the rotating part 1 are such that no blind angles may occur between the transmitting and the receiving units.

Alternatively, the communication between the stationary and rotating communication units 34, 29 may take place capacitively or inductively, or by radio communication.

The rotating exciter G3 is of synchronous-machine type with a rotating stator winding, which is excited by a smaller static exciter, comprising converters 42 for supplying the stationary field winding 44. The static exciter is supplied from the auxiliary power generator G2 and the excitation is controlled by the regulator equipment 33 by controlling the supply voltage of the converter bridge 42. The supply voltage to the thyristor bridge 21, which in turn supplies the field winding 30 of the machine G1, may thus be regulated by changing the magnetic flux in the rotating exciter G3.

The auxiliary power generator G2 further supplies a busbar 36 for distribution of the auxiliary power via equipment 35 for voltage, and possibly frequency, adaptation.

The output voltage of the machine G1 is fed back, via a connection 46, to the regulator equipment 33 for automatic adaptation of the supply voltage of the rectifying semiconductor elements 21 to the actual operating conditions.

By such a requirement-adapted control of the supply voltage of the thyristor bridge 21, the losses in the rotating exciter G3 are reduced. In case of transients currents, the field voltage may be increased. Stationary operation stability thus entail a low peak-voltage factor and transient stability entails a high peak-voltage factor. The peak-voltage factor may be defined as the ratio of the maximum possible field voltage and the field voltage at rated load and a hot field winding. Compare with the description of Figure 5 below.

During stationary operating conditions, the voltage of the exciter G3 is thus increased or decreased in proportion to the desired value fed into the regulator equipment 33. During transient stability and voltage regulation (the regulator may alternatively be arranged as a field-current regulator), the supply voltage is increased to a maximum value until stationary operation stability has been re-
5 stored. The return to the actual voltage level for stationary operation stability may then be performed either instantaneously or via a ramp function with a controlled rate of change. The control pulse generator 22, with the function of compensating the firing instants of the thyristors 21 in case of voltage variations, maintains the
10 field current constant during the transition process.

The line voltage may be fed back to the regulator equipment 33, via a connection 48, for use when phasing the machine G1.

Figure 2 shows an alternative embodiment, in which the auxiliary power generator G2 is a synchronous machine and the rotating part 1 comprises an ex-
15 citer G3 in the form of a permanent-magnet generator with double stator windings for excitation of the machine G1 and the auxiliary power generator G2 via a respective thyristor bridge included in the rotating part 1. In this embodiment, the rotating part 1 thus comprises a unit 51 of a power stage, an overvoltage protection device and control equipment for supplying the field winding 30 of the ma-
20 chine G1, as well as similar devices, represented by the block 52 in Figure 2, for supplying the auxiliary power generator G2.

In the same way as the control equipment 23 for the excitation of the main machine G1 is connected to stationary regulator equipment 53 via communication units 29, 34 for wireless communication, as described with reference to Figure 1,
25 the corresponding control equipment for the excitation of the auxiliary power generator G2 is connected to the regulator equipment 53 via identical communication units 54, 57. In this embodiment, the regulator equipment 53 comprises two voltage regulators 58, 59 for maintaining constant the voltages of both the machine G1 and the auxiliary power generator G2 by excitation control.

30 The permanent-magnet generator G3 comprises a stationary permanent-magnet rotor 60, supplemented by a few winding turns 61, which are supplied via the converter 62 from the auxiliary power generator G2 for controlled flux

changes. In such a permanent-magnet rotor 60, there is always a field even at zero voltage.

The control pulse generation for the thyristor bridges is based on a principle for self-compensation for variations in the supply voltage of the thyristor
5 bridges. Flux changes which are necessary for voltage variations for adaptation to the excitation requirement of the machine G1 will thus not influence the excitation of the voltage-regulated auxiliary power generator G2.

The voltage regulation of the auxiliary power generator G2 is made possible by the voltage regulator 58 included in the regulator equipment 53, which
10 voltage regulator makes it possible either to maintain a constant voltage on the auxiliary power busbar 36, ALT. 2, or to increase the voltage for temporary generation of extra short-circuit power in case of a fault, ALT. 1. The voltage of the auxiliary power generator G2 is thus increased by increasing its excitation.

In the embodiment shown in Figure 2, the auxiliary power generator G2 is
15 a synchronous machine, as mentioned above, of a size smaller than that of machine G1. Also the power stage 52 for supplying the field to the auxiliary power generator G2 is smaller than the corresponding power stage 51 for supplying the field of the machine G1.

The other parts of the embodiment of Figure 2 are identical with the corresponding parts of the embodiment shown in Figure 1 and will therefore not be described in more detail here.
20

Figure 3 shows another embodiment of the power plant according to the invention. This embodiment differs from the embodiment shown in Figure 2 in that the exciter G3 is of an asynchronous machine type with double rotor windings for
25 excitation of the machine G1 and the auxiliary power generator G2.

The asynchronous machine G3 with reversed direction of rotation functions as a rotating transformer and also makes possible excitation during downtime.

In addition to the change of the exciter G3 described above, this embodiment
30 corresponds to the one described in Figure 2 and will not, therefore, be described in more detail here.

Figure 4 shows in more detail an embodiment of the rotating part 1 in the embodiments according to the preceding figures. The rotating part 1 thus comprises a part 71 for excitation and protection of the machine G1. The part 71 comprises a thyristor bridge 81 with a control pulse generator 82, which has been described above, connected to the output of a selector 83, which is adapted to select the smallest of an input signal in the form of a control signal from the regulator device (not shown), received over the wireless communication units 93, 94, and a signal from a regulator unit 85. This regulator unit 85 is adapted to receive, as input signals, a set-point or limit-value signal from the communication unit 93 as well as a signal representing the field current I_{field} , measured by means of the current-measuring device 95, for manual control or limitation of the field current.

Further, a current-measuring unit 86 is connected to the communication unit 93 and to the current transformers 87 for measuring the alternating currents from the rotating exciter G3, in this case of a permanent-magnet generator type, and supplying corresponding measurement signals I_r , I_s , I_t to the communication units 93.

The current on both the direct-voltage side and the alternating-voltage side is measured with the current-measuring devices 95 and 86, 87, respectively, and the difference current is used as a criterion for resetting the overvoltage protection device 84, the resetting being performed with the aid of a temporary negative excitation voltage.

A voltage-measuring unit 89 is adapted to measure the voltage on the output of the rotating exciter G3 with a filter transformer 88, as described above, and to supply corresponding signals U_r , U_s , U_t to the communication unit 93. The voltage signal sensed by the transformer 88 is also supplied to the control pulse generator 82, where it is compared with the signal from the selector 83 for controlling the thyristor bridge 81 in dependence thereon.

Still another voltage-measuring unit 70 is adapted to measure the field voltage and to supply a corresponding measurement signal U_{field} to the communication unit 93 for transmission to the stationary communication unit 94 and the regulator equipment.

Further, there is a bidirectional overvoltage protection device 84 for the field winding 64 of the machine G1 as previously described.

A unit 71 for detection of ground fault in the field winding 64 as well as a transducer 72 for measuring the temperature of the field winding 64 are also provided.

Figure 4 further shows the permanent-magnet rotor 60 of the exciter G3 with a supplementary winding 61, as described with reference to Figure 2, as well as a feedback connection 46 from the machine G1 to the regulator equipment and a connection 48 for supplying a measured line voltage to the regulator equipment, as described with reference to Figure 1.

Figure 5 shows a diagram illustrating a solution in principle for reduction of exciter losses by adapting the requirement of the supply voltage to the rotating thyristor bridge. $U_{f/0}$ designates the field voltage in an unloaded machine, $U_{f/1}$ designates the field voltage at rated load on the machine, U_{fc} designates maximum field voltage during stationary operation (stationary operation stability), U_{peak} designates maximum field voltage during transient operation (transient stability), U_{ac} designates the supply voltage of the thyristor bridge, and U_{dc} designates the actual field voltage = $1.35 \times U_{ac} \times \cos \alpha$.

In case of transient disturbances, the maximum field voltage U_{peak} thus increases, at t_1 , as does the peak-voltage factor, which is defined above. In this way, improved efficiency of the rotating exciter during steady-state conditions is obtained.

Figure 6 illustrates in more detail the principle of self-compensating control-pulse generation for the thyristor bridge in the power plant according to the invention.

From the filter transformer 88, the control pulse generator 82 is supplied with the phase voltages U_R , U_S , U_T (cf. Figure 4 and the upper curve of Figure 6). An internal auxiliary voltage $U+R$, which is shifted in phase 60 electrical degrees from the phase voltage U_R , is generated. The output signal UC of the regulator 83, 85 in Figure 4 is supplied to the control pulse generator 82 and is compared in a comparator with the auxiliary voltage $U+R$ and when the signal UC is equal to the auxiliary voltage $U+R$ and U_S is greater than U_R , a firing signal is

supplied to the relevant thyristor in the S-phase in the bridge 81 in Figure 4, marked in the lower part of Figure 6, whereupon the conduction interval of the thyristor follows.

The firing instant is thus controlled both by the changes in the regulator
5 signal U_c and by changes in the signal level of the internal auxiliary voltage $U+R$.

To enable direct connection of the electric machine and possibly the auxiliary power machine, as previously discussed, the machine has windings, comprising an insulated conductor of the kind shown in Figure 7. Figure 7 thus shows a cross-section view of an insulated conductor 11 comprising a number of strands
10 35 with a circular cross section of, for example, copper (Cu). These strands 35 are arranged in the centre of the insulated conductor 11. A first semiconducting layer 13 is arranged around the strands 35. An insulating layer 37, for example an XLPE insulation, is arranged around the first semiconducting layer 13. A second semiconducting layer 15 is arranged around the insulating layer 37. The insulating
15 conductor or cable is bendable and this property is maintained in the insulated conductor during its service life, and the three layers mentioned are designed so as to adhere to one another even when the cable is bent. The insulated conductor has a diameter in the interval 20-250 mm and a conductor area in the interval 80-3000 mm².

20 A plurality of modifications of the embodiments described above are, of course, possible. Thus, for example, the phase position for the supply voltage of the converter may be transformed to the stationary side, which makes possible a stationarily arranged control pulse generator and transmission of the starting instant of the firing pulses to the rotating part in a wireless manner, as described
25 above. Further, for example, the supply voltage to the rotating supply part may be transformed to the rotating part by means of a ring transformer. According to additional possible alternatives, current, voltage and temperature measurement may be realized by the use of fibre-optic technology.

CLAIMS

1. An electric power plant, comprising at least one rotating electric machine, intended to be connected directly to a distribution or transmission network and
- 5 comprising at least one electric winding, **characterized** in that the winding comprises at least one electric conductor, a first layer with semiconducting properties surrounding the conductor, an insulating layer surrounding the first layer, and a second layer with semiconducting properties surrounding the insulating layer, and in that a brushless excitation system is adapted to excite the electric machine.
- 10
2. A power plant according to claim 1, **characterized** in that the potential of the first layer is essentially equal to the potential of the conductor.
3. A power plant according to claim 1 or 2, **characterized** in that the second
- 15 layer is adapted to form essentially an equipotential surface surrounding the conductor.
4. A power plant according to claim 3, **characterized** in that the second layer is connected to a predetermined potential.
- 20
5. A power plant according to claim 4, **characterized** in that said predetermined potential is ground potential.
6. A power plant according to any of the preceding claims; **characterized** in
- 25 that at least two adjacent layers of the winding of the machine have essentially equal coefficients of thermal expansion.
7. A power plant according to any of the preceding claims, **characterized** in that the conductor comprises a number of strands, at least some of which being in
- 30 electrical contact with one another.

8. A power plant according to any of the preceding claims, **characterized** in that each one of said three layers is fixed to adjacent layers along essentially the whole contact surface.
- 5 9. A power plant according to any of the preceding claims, **characterized** in that said layers are adapted to adhere to one another even when the insulated conductor is bent.
10. An electric power plant, comprising at least one rotating electric machine
10 of alternating-current type, intended to be connected directly to a distribution or transmission network and comprising at least one magnetic core and at least one electric winding, **characterized** in that the winding is formed from a cable comprising one or more current-carrying conductors, each conductor having a number of strands, an inner semiconducting layer arranged around each conductor, an
15 insulating layer of solid insulating material arranged around said inner semiconducting layer, and an outer semiconducting layer arranged around the insulating layer, and in that a brushless excitation system is adapted to excite the electric machine.
- 20 11. A power plant according to claim 10, **characterized** in that said cable comprises a sheath.
12. A power plant according to any of the preceding claims, **characterized** in that the brushless excitation system comprises a rotating part with an exciter,
25 connected to controllable semiconductor elements with associated control equipment for rectifying the supply voltage obtained for supplying the field winding of the machine.
13. A power plant according to claim 12, **characterized** in that a communication unit is adapted for wireless communication between stationary regulator
30 equipment and the control equipment included in the rotating part.

14. A power plant according to claim 12 or 13, **characterized** in that the exciter is of synchronous machine type with a rotating stator winding.

15. A power plant according to claim 12 or 13, **characterized** in that the exciter comprises a permanent-magnet generator, in which stationary permanent magnets are supplemented by winding turns for controlled changes of the flux.

16. A power plant according to claim 12 or 13, **characterized** in that the exciter comprises an asynchronous machine with three rotating windings and reversed direction of rotation.

17. A power plant according to any of claims 12 - 16, comprising a machine for auxiliary power generation, **characterized** in that the exciter is designed with double stator windings for supplying the electric machine or the main machine as well as the auxiliary power machine.

18. A power plant according to claim 17, **characterized** in that the stator windings are connected to each of their respective controllable semiconductor elements with respective control equipment for individual control of the supply of the auxiliary power machine and the electric machine.

19. A power plant according to claim 17 or 18, **characterized** in that the control equipments are adapted to generate control pulses to the controllable semiconductor elements in a manner self-compensating for variations in the supply voltage to the semiconductor elements.

20. A power plant according to any of claims 12-19, **characterized** in that the controllable semiconductor elements are adapted to form a thyristor bridge.

21. A power plant according to any of claims 12-20, **characterized** in that a filter transformer is adapted to determine the phase position for firing the controllable semiconductor elements for adaptation of the voltage.

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22. A power plant according to any of claims 13-21, **characterized** in that the communication unit comprises stationary transmitters and/or receivers connected to the regulator equipment as well as receivers and/or transmitters on the rotating
5 part connected to the control equipment for communication therebetween with frequency-modulated infrared light.

23. A power plant according to any of claims 17-22, **characterized** in that the auxiliary power machine is adapted, via the converter, to supply the stationary
10 field winding of the rotating exciter.

24. A power plant according to any of claims 17-23, **characterized** in that the output voltage of the auxiliary power machine is fed back, via a regulator, to the controllable semiconductor elements for the auxiliary power machine for regulat-
15 ing the voltage by excitation control.

25. A power plant according to any of claims 13-24, **characterized** in that the stationary part and the rotating part of the communication unit are adapted for wireless communication, capacitively or inductively or by radio communication or
20 optical connection.

26. A power plant according to any of the preceding claims, **characterized** in that a unit is adapted to detect ground faults in the supply of the field winding of the electric machine.
25

27. A power plant according to any of the preceding claims, **characterized** in that transducers are adapted to measure the temperature in the field winding of the electric machine.

30 28. A power plant according to any of claims 12-27, **characterized** in that an overvoltage protection device, controlled by the control equipment, is connected across the field winding of the electric machine.

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17

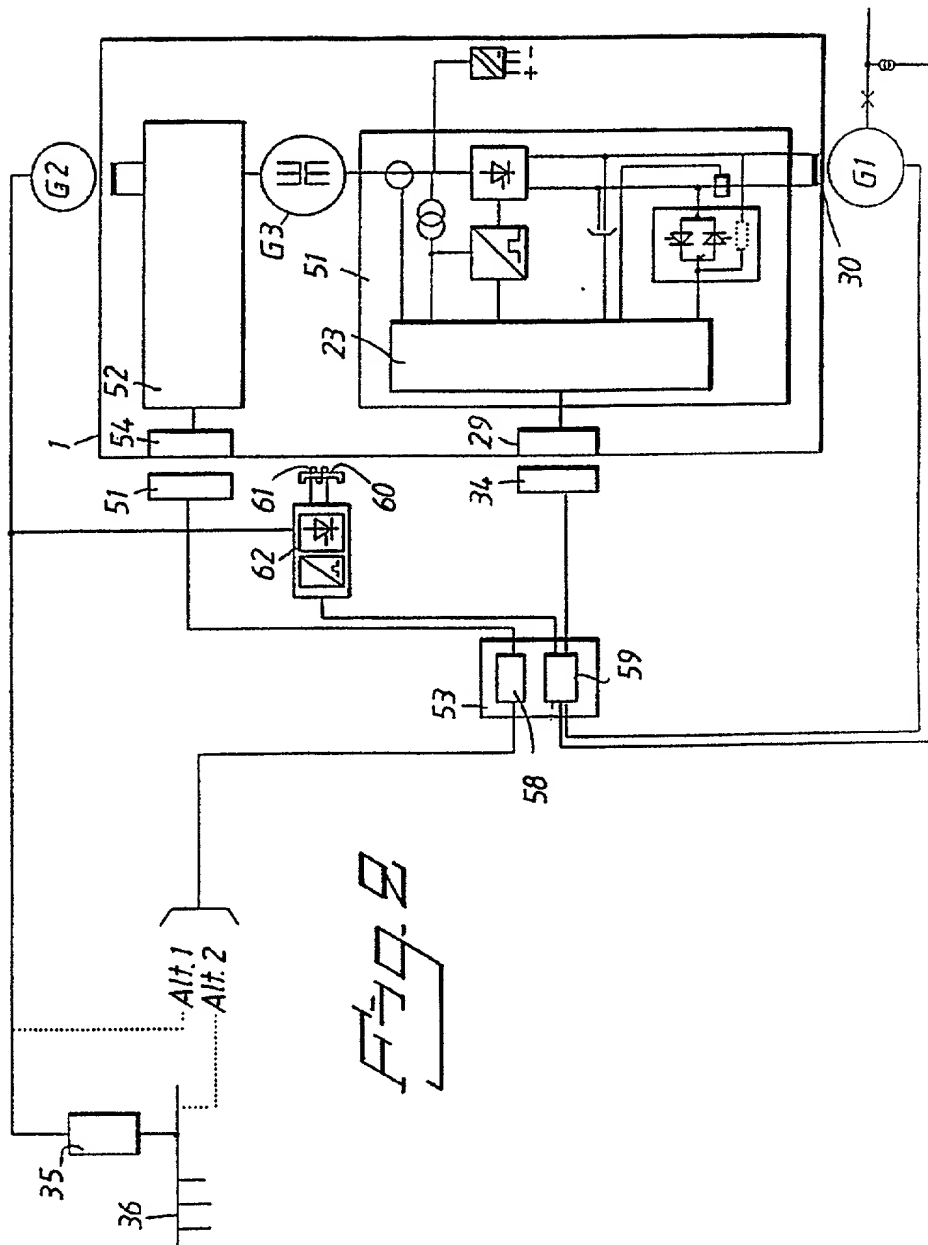
29. A power plant according to claim 28, **characterized** in that current-measuring means are arranged on the AC and DC sides of the controllable semiconductor elements, and that the overvoltage protection device is adapted to be
5 reset in response to the difference between these currents fulfilling a predetermined condition.

30. A power plant according to any of claims 13-29, **characterized** in that the output voltage of the electric machine is fed back to the regulator equipment for
10 adaptation of the supply voltage to the actual operating conditions.

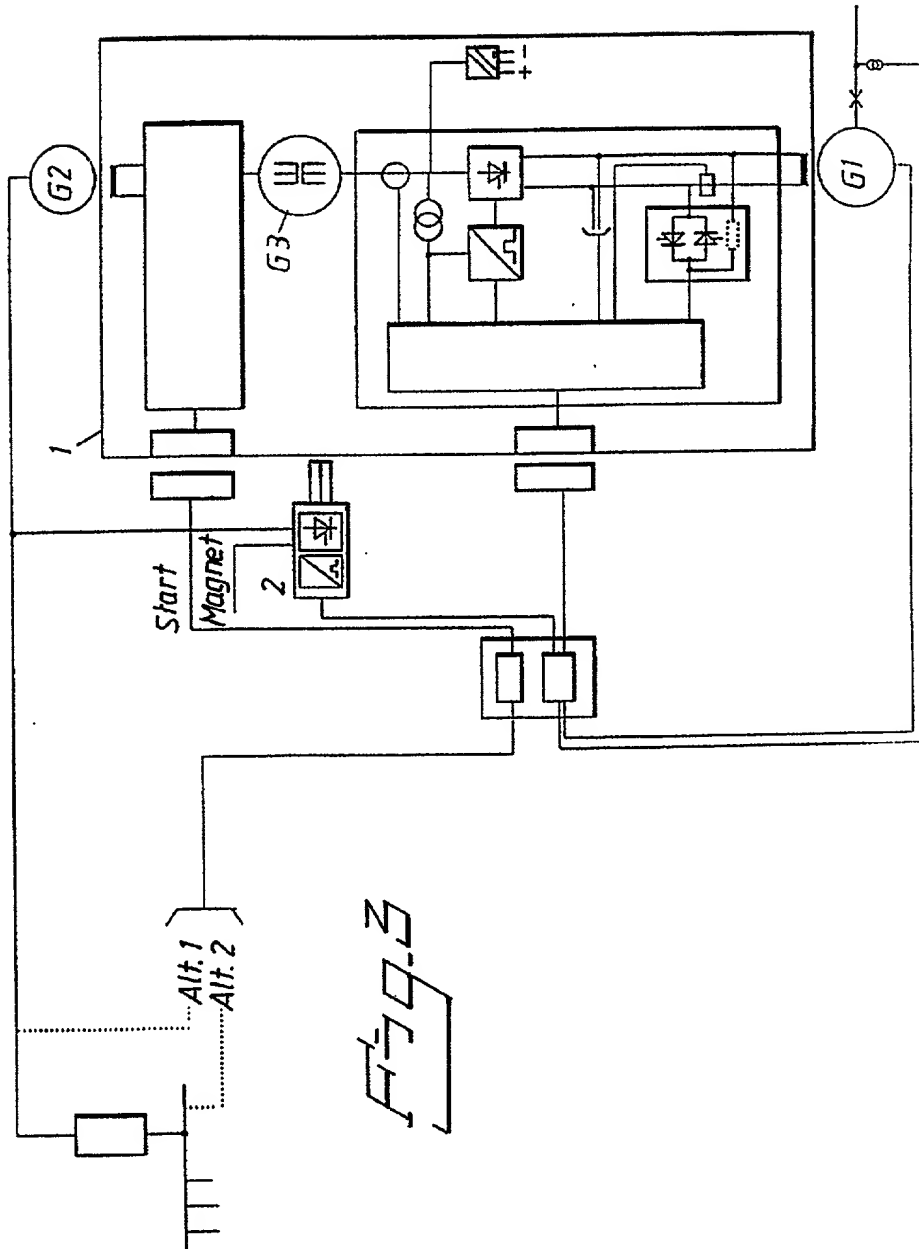
31. A power plant according to any of claims 17-30, **characterized** in that the auxiliary power machine comprises at least one electric winding with at least one electric conductor, a first layer with semiconducting properties surrounding the
15 conductor, an insulating layer surrounding the first layer, and a second layer surrounding the insulating layer.

32. Use of a rotating electric machine in an electric power plant according to any of the preceding claims, said machine being intended to be connected directly
20 to a distribution or transmission network and comprising at least one electric winding, said winding comprising at least one electric conductor, a first layer with semiconducting properties surrounding the conductor, an insulating layer surrounding the first layer, and a second layer with semiconducting properties surrounding the insulating layer, and a brushless excitation system for exciting the
25 electric machine.





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Fig. 4

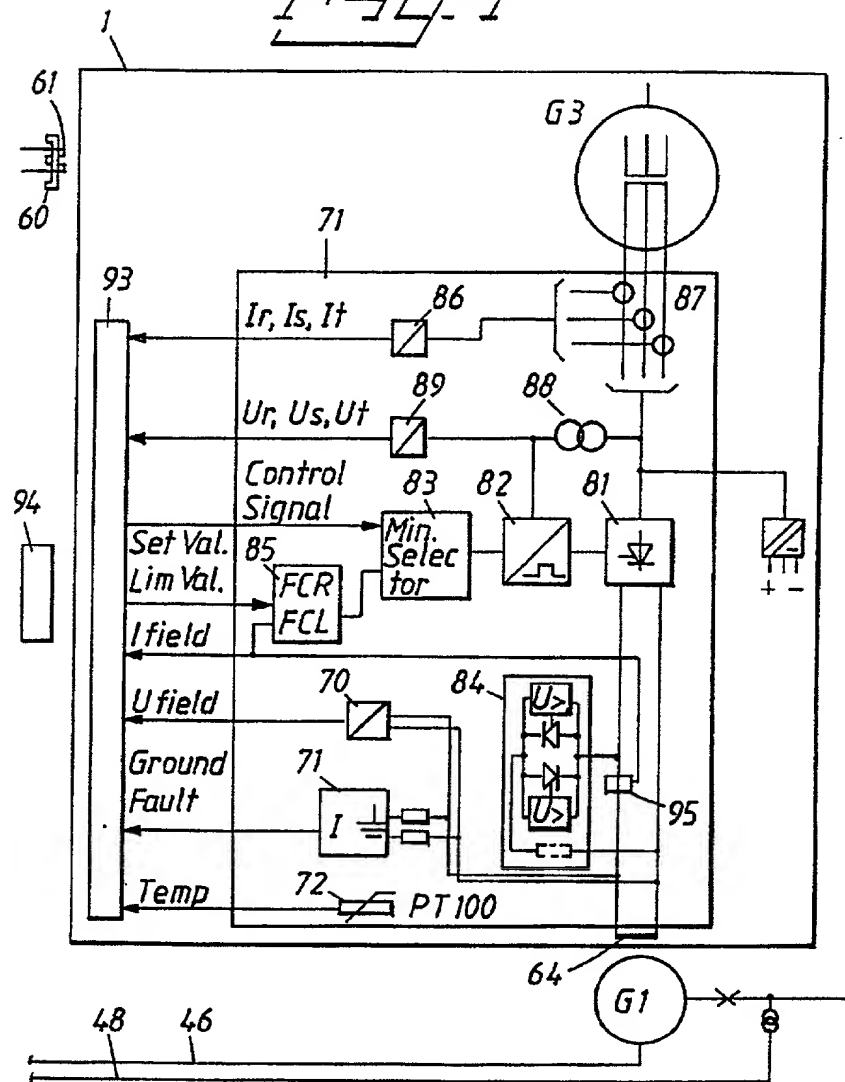
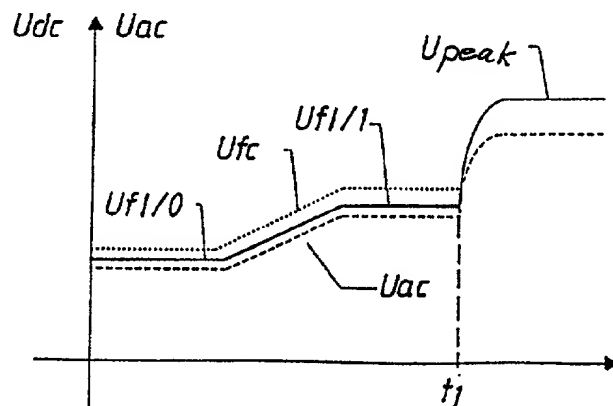


Fig. 5



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Fig. 6

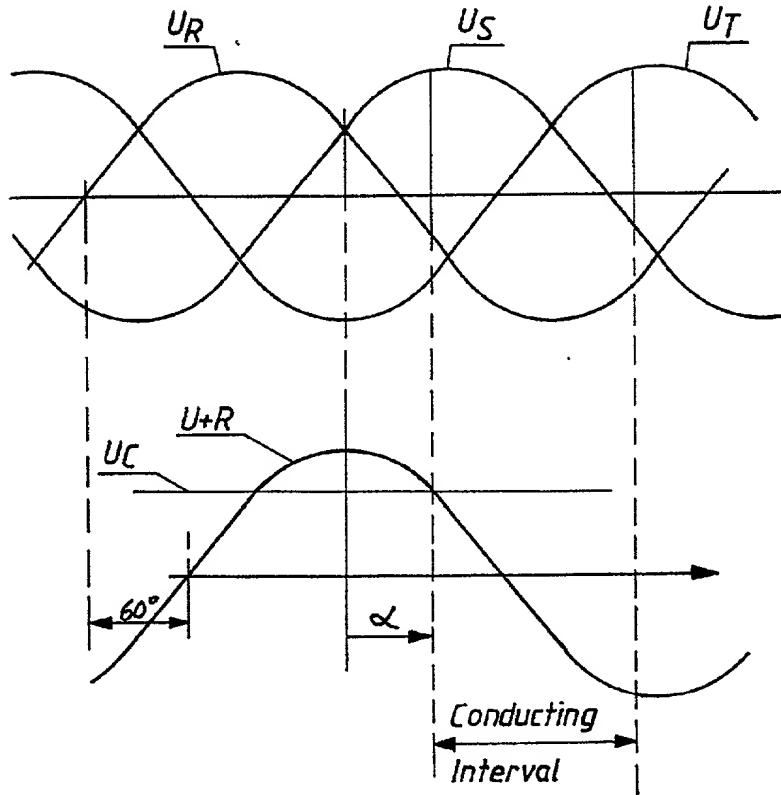
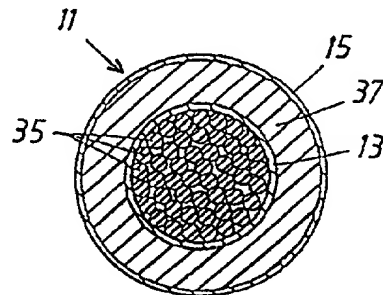


Fig. 7



COMBINED DECLARATION AND POWER OF ATTORNEY
FOR UTILITY PATENT APPLICATION (Includes PCT)

Attorney Docket No.
705/72341-2

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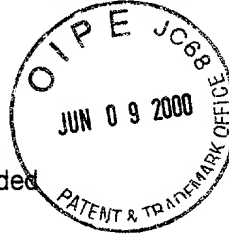
As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name; that

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural inventors are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: AN ELECTRIC POWER PLANT

the specification of which (check one): ☐ is attached hereto.

☐ was filed on _____ amended
on _____



☒ was filed as PCT international application no. PCT/SE98/01738 on 29 September 1998, and was amended under PCT Article 19 on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I do not know and do not believe the claimed invention was ever known or used in the United States of America before my or our invention thereof, or patented or described in any printed publication in any country before my or our invention thereof or more than one year prior to this application, that the same was not in public use or on sale in the United States of America more than one year prior to this application, that the invention has not been patented or made the subject of an inventor's certificate issued before the date of this application in any country foreign to the United States of America on an application filed by me or my legal representatives or assigns more than twelve months prior to this application.

I hereby claim foreign priority benefits under Title 35, United States Code §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application(s) on which priority is claimed:

Prior Foreign Application(s)			Priority Claimed	
<u>9703552-1</u>	<u>Sweden</u>	<u>30 September 1997</u>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(Number)	(Country)	Day/Month/Year Filed	Yes	No
_____	_____	_____	<input type="checkbox"/>	<input type="checkbox"/>
(Number)	(Country)	Day/Month/Year Filed	Yes	No

I hereby claim the benefit under Title 35, United States Code, §119 (e) of any United States provisional application(s) listed below:

Application No. Filed	Day/Month/Year Filed	Application No.	Day/Month/Year
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829245

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) or PCT international application(s) designating the United States of America listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior application(s) in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

Application Serial No. Filing Date Status (patented, pending, abandoned)


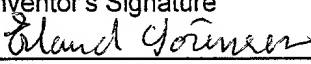
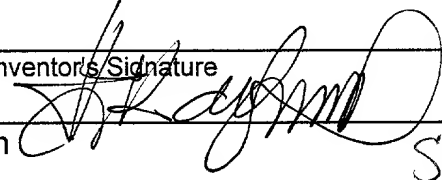
Application Serial No. Filing Date Status (patented, pending, abandoned)

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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